through the imaging pipeline, manipulating the frame buffer to have stored therein color data of the 3D image which is to be rendered at each pixel based on the indication stored during the initial pass through the imaging pipeline.

41. 37. (New) The graphics system of claim 14, wherein said imaging pipeline further comprises:

a stencil buffer containing stencil bits for each pixel in the display scene; and

a stencil test module constructed and arranged to set said stencil bits to indicate which 3D image is closest to the viewpoint based on the results of the depth test.

REMARKS

1. In response to the Office Action mailed April 12, 2002, Applicants respectfully request reconsideration. Claims 1-31 were originally presented for examination. All of the claims were rejected in the first Office Action. By the foregoing Amendments, claims 2, 3, 6, 10, 13, 14, 18, 19, 21, 28, 30 and 31 have been amended. Claims 5, 9, 11, 12 and 15-17 have been canceled without prejudice or disclaimer, and claims 32-37 have been added. Thus, with entry of this paper, claims 1-4, 6-8, 10, 13, 14 and 18-37 are pending in this application. Of these 30 claims, five claims (claims 1, 18, 27, 28 and 31) are independent. These amendments are believed not to introduce new matter and their entry is respectfully requested.

2. Based upon the above Amendments and following Remarks, Applicants respectfully request that all outstanding objections and rejections be reconsidered, and that they be withdrawn.

Amendments To The Specification

3. The title of the application has been amended to more clearly reflect Applicants' claimed invention. Entry is respectfully requested.

Claim Rejections Under 35 U.S.C. §103

4. The Examiner has rejected claims 1-35 under 35 U.S.C. 103(a) as being unpatentable over U.S. Patent No. 5,760,781 to Kaufman *et al.* (hereinafter "Kaufman"). Specifically, the Examiner asserts that Kaufman teaches a two-dimensional (2D) imaging

pipeline, and that it would have been obvious to a person of ordinary skill in the art at the time the invention was made to "configure Kaufman's system as claimed [in Applicants' independent claims]." The sole support provided by the Examiner in this obviousness rejection is "3D data [is converted] to 2D data to store in 2D buffers." (*See*, Office Action, pg. 2.)

5. Applicants respectfully traverse this rejection. First, Kaufman does not disclose implementing a two-dimensional imaging pipeline as suggested by the Examiner. Second, the art of record neither teaches nor suggests modifying Kaufman to implement a 2D imaging pipeline. Third, there is no teaching or suggestion on the art of record to composite separately-generated 3D images in any manner, let alone using a modified, 2D imaging pipeline as recited in Applicants' independent claims. Based on these facts, Applicants respectfully assert that a *prima facia* case for obviousness has not been made by the Examiner, requiring withdrawal of the outstanding Section 103 rejections.

Kaufman Neither Teaches Nor Suggests a 2-Dimensional Imaging Pipeline

6. Kaufman is directed to a graphics system that performs real-time processing of voxels. To facilitate an understanding of the distinctions between Applicants' claimed invention and the system disclosed in Kaufman, Applicants offer the following information derived from pages 1-2 and 177-178 of "Introduction to Volume Rendering" by Barthold Lichtenbelt, Randy Crane and Shaz Naqvi, Prentice Hall PTR, 1998 (hereinafter "Lichtenbelt"). The authors of this book were Hewlett-Packard employees at time of publication, and the book is commercially available from Prentice Hall as one of the "Hewlett-Packard professional books." A copy of these and other pages of Lichtenbelt cited below are enclosed herewith as Attachment 1. Note that this information is being submitted for informational purposes only and not as prior art to Applicants' claimed invention. Accordingly, the excerpts are being submitted as an attachment to this paper rather than under 37 CFR §1.96.

7. The operations performed by graphics systems to process voxels are collectively referred as voxel or volume rendering. Volume rendering is a method for directly rendering a volume data set, or volume, to show the characteristics of the interior of a solid object when displayed on a two-dimensional computer monitor. A volume data set is a three-dimensional array of data points referred to as volume elements, or voxels. A

voxel can be thought of as the three-dimensional analogue of a pixel; that is, a three-dimensional volume element representing a discrete sample of a volume in three-dimensional space. Voxels are commonly defined as sample points separated by a finite distance, with each voxel having a position and a value. The position of a voxel specifies the x,y,z coordinates of the center of the voxel in the 3D volume data set. The value of the voxel depends on its format. For example, a voxel can have an intensity value and an index value. Volume data sets can be generated by numerous means, but most commonly by some method of three-dimensional scanning or sampling and by numerical modeling. For example, a volume data set may be generated by magnetic resonance imaging (MRI), wherein the density of human or animal tissue is computed at each point of a 3D grid. A display of this information could indicate the boundaries of the various types of tissue, as indicated by density changes. (*See*, Lichtenbelt, pp. 1-2 and 177-178.)

8. Kaufman discloses a graphics system that utilizes multiple 2D buffers and a high-speed bus to attain pipelined and parallel voxel rendering capabilities. (*See*, Kaufman, col. 2, ln. 60- col. 3, ln. 53.) Referring to Figure 2, Kaufman's volume visualization system operates by casting viewing rays 12 that originate at a pixel in the projection plane through a cubic frame buffer 22 along a selected viewing direction. In contrast to the then-conventional systems, Kaufman incorporates multiple 2D buffers in the manner disclosed in Figures 3 and 12 to increase the speed and efficiency of the volume rendering process. Referring to these illustrative embodiments, the Kaufman apparatuses 20 and 70 include a cubic frame buffer 22 operationally connected to three 2D buffers 24. Each of the 2D buffers 24 are used as 2D voxel storage devices. The interconnecting mechanism between the buffers supports high-bandwidth transfer of beams of voxels from the cubic frame buffer 22 to the 2D buffers 24. (*See*, Kaufman, col. 6, lns. 20-63.)

9. A volume rendering pipeline (that is, the pipeline disclosed in Kaufman) is not the same as a 2D imaging pipeline or a 3D primitive-rendering pipeline. These rendering pipelines are briefly described below. The two-dimensional imaging pipeline for processing 2D images and the three-dimensional primitive rendering pipeline for processing primitives are described in Applicants' application:

> There are two paths through a rendering pipeline, one for primitive data and one for pixel data. The former path processes three-dimensional (3D) primitive data to form a two-dimensional (2D) image for display on a 2D display screen. The latter path manipulates pixels, images and bitmaps of existing 2D images. The Cartesian coordinates of an image include X and Y coordinates corresponding to the pixel address in the horizontal and vertical dimensions of the display screen, and the Z coordinate which is orthogonal to the display screen and represents the distance from the location of the viewer, referred to as the viewpoint. The former path is referred to herein as a 3D pipeline due to the inclusion of depth information (Z coordinate data) in the primitive data. In contrast, the latter path is referred to as a 2D pipeline due to the absence of Z coordinate data from the 2D image data. This is because only the address (X,Y coordinate) and color (R,G,B,A) data is required to display a 2D image on a 2D display screen.
>
> (*See*, Applicants' application, pg. 3, ln. 26-pg. 4, ln. 8.)

10. Neither of these pipelines are capable of processing voxels without substantial modifications being made to them. To process voxels, a graphics system must implement an additional pipeline, a volume rendering pipeline, that performs sequential operations on voxels. Such a volume rendering pipeline is described at pages 28-30 and 173-176 of Lichtenbelt. Copies of these pages are included in Attachment 1. Briefly, a volume rendering pipeline includes segmentation, gradient computation, resampling, classification, shading and compositing stages. These voxel-processing stages perform operations that are not and cannot be performed in conventional 2D imaging or 3D primitive-rendering pipelines. Thus, there are three different types of rendering pipelines each having a specific structure to perform specific operations on a specific type of data: a 2D imaging or pixel pipeline renders 2D images; a 3D or geometric pipeline renders primitives; and a volume or voxel rendering pipeline renders voxels. There is no capability provided in one rendering pipeline to perform the operations of the other. Thus, appropriate hardware and software have to implemented in a graphics system to provide the desired rendering capability.

11. Kaufman discloses performing voxel processing operations using a volume rendering pipeline that includes multiple 2D buffers and a high-speed bus. This arrangement provides benefits over then-conventional systems which, according to Kaufman, implemented a single 2D buffer and conventional bus. Applicants respectfully assert that the implementation of an additional 2D buffer and a high-speed bus in a volume rendering pipeline does not convert that volume rendering pipeline into a 2D rendering pipeline. In fact, the Kaufman volume rendering pipeline does not include any elements of a 2D imaging pipeline and, therefore, cannot process 2-dimensional images. Nor do such modifications enable the Kaufman graphics system to composite separately-generated 3D images. Kaufman discloses only a volume rendering pipeline (or portion thereof) capable of rendering voxels, not images. Accordingly, Applicants respectfully assert that Kaufman does not disclose a 2D imaging pipeline as asserted by the Examiner.

There is no motivation in the art of record to modify Kaufman as proposed in the office action

12. Applicants assert that there is no suggestion in the art of record to modify Kaufman to utilize a two-dimensional graphics imaging pipeline. As noted, only volume rendering operations are performed in the Kaufman system. Neither Kaufman nor the other art of record provide the motivation to modify Kaufman to convert the volume rendering pipeline into a 2D imaging pipeline. Applicants further assert that the art of record provides no motivation whatsoever to composite separately-generated 3D images. In fact, the art of record is silent with regard to performing such operations or achieving such an objective. Thus, there is no teaching or suggestion in the art of record to modify Kaufman to render images, including 2-dimensional images which can be rendered by conventional 2D imaging pipelines, or 3-dimensional images which can be rendered by a 2D imaging pipeline as configured in Applicants' claimed invention.

13. Thus, the Examiner has failed to provide any *evidence*, whether in the form of some teaching, suggestion, incentive or inference in Kaufman or other art of record, or in the form of generally available knowledge, that one having ordinary skill in the art *would have been led* to modify the relevant teachings of Kaufman in the proposed manner. This is because no such motivation exists in the applied references. Thus, the only conclusion that can be drawn, based on the record of this application, is that the suggestion forming the basis for the Examiner's otherwise factually unsupported conclusion must have come

from Applicants' own novel disclosure; that is, they are based on impermissible hindsight. It is too well-settled for citation that an applicant's own novel disclosure cannot be used to supply the teaching or suggestion that is missing from the known art. Furthermore, for the reasons set out above, Applicants assert that even if one of ordinary skill at the time of the invention were motivated to modify Kaufman as proposed by the Examiner, the resulting system would not contain nor would it have the advantages of Applicants' invention as recited in the independent claims. For at least these reasons, Applicants respectfully request that the rejection under Section 103 of the independent claims be reconsidered, and that they be withdrawn.

14. Dependent claims 2-4, 6-8, 10, 12-14, 19-26 and 29-30 depend directly or indirectly from independent claims 1, 18, 28, 28 and 31 and incorporate all of the subject matter of their respective independent claim. Furthermore, these dependent claims add additional subject matter which makes them independently patentable in and of themselves over the art of record. Accordingly, Applicants respectfully request that the rejection of the dependent claims be reconsidered, and that they be withdrawn.

List of Attachments

15. The following attachments form part of this Response and Amendment:

Attachment 1: Introduction to Volume Rendering" by Barthold Lichtenbelt, Randy Crane and Shaz Naqvi, Prentice Hall PTR, 1998, pgs. 1-5, 28-30, and 173-178

Attachment 2: Marked-Up Version of Claims Showing All Changes Made

Attachment 3: Marked-Up Version of Specification Showing All Changes Made

CONCLUSION

16. In view of the foregoing Amendments and Remarks, this application should now be in condition for allowance. A notice to this effect is respectfully requested.

Respectfully submitted
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Docket No. 10981094-1
Date: ~~July 1, 2002~~
July 12, 2002

MARKED-UP VERSION OF CLAIMS
SHOWING ALL CHANGES MADE

[ATTACHMENT 2 TO THE AMENDMENT AND RESPONSE FILED IN RESPONSE TO THE OFFICE ACTION DATED APRIL 12, 2002 IN U.S. PATENT APPLICATION 09/547,065.]

2. (Amended) The graphics system of claim 1, wherein said 2D and 3D [two-dimensional] images [and said three-dimensional images] are represented by pixel data.

3. (Amended) The graphics system of claim 1, wherein the graphics system comprises a rendering pipeline [including,] comprising:

a geometric pipeline constructed and arranged to generate a two-dimensional image from one or more model views represented by primitive data; and

said imaging pipeline.

6. (Amended) The graphics system of claim [5,] 1,

wherein the graphics system further comprises a frame buffer for storing pixel data to be displayed on a display device, and

wherein said 3D images to be composited comprise:

a stored image stored in the frame buffer; and

a next image to be composited with the stored image.

10. (Amended) The graphics system of claim 14, [9,]

wherein [said pixel data of said stored image and said next image comprise color data] for each pixel, [and wherein] said imaging pipeline writes [color data] to [the] a frame buffer of the graphics system the color data of [one of] the 3D image that is closest to the viewpoint. [either said stored or said next image based on said indications of said selected image.]

13. (Amended) The graphics system of claim 1, [8,] wherein said 3D images are represented by pixel data comprising [of said next image includes] Z coordinate data, color data and X,Y coordinate data, wherein [an image compositing module of] said

imaging pipeline receives said Z coordinate data [and said color data] over a [color] data channel of the imaging pipeline configured to transfer data other than Z coordinate data, and receives said X,Y coordinate data over an address data channel.

14. (Amended) The graphics system of claim 1, [13,] wherein said imaging pipeline [image compositing module] comprises:

a depth buffer configured to store Z coordinate data for each pixel in a display scene; and

a depth test module constructed and arranged to compare Z coordinate data of said 3D images, [stored image and said Z coordinate data of said next image,] and to store in said depth buffer Z coordinate data of each pixel of the 3D [either said next or stored] image that is closest to scene viewpoint. [passed said depth test.]

18. (Amended) A method for compositing 3D images in a 2D imaging pipeline to form a composited image comprising:

storing in a frame buffer a stored 3D image including color data and Z coordinate data;

processing in the 2D imaging pipeline Z coordinate data of a next 3D image to determine whether the stored or next 3D image is to be rendered at each pixel in the composited image; and

replacing said stored color data with color data of said next 3D image for each pixel at which the next 3D image is to be rendered in the composited image. [at a pixel.]

19. (Amended) The method of claim 18, wherein said processing Z coordinate data comprises:

transferring Z coordinate data of the next image through an available data channel of imaging pipeline;

depth testing the stored and next images;

updating a depth buffer as necessary to store [with] Z coordinate data of a closest image; and

recording an indication of which 3D image is the closest image.

21. (Amended) The method of claim 18, wherein the imaging pipeline consists of a color data channel and an address data channel, and wherein replacing the stored color data comprises:

receiving over [routing selectively] the color data channel [to a depth test module] the color data of the next 3D image, and

storing the color data of the next 3D image when the recording step records an indication that the next 3D image is the closest 3D image.

28. (Amended) A graphics system comprising [an] a two-dimensional imaging pipeline configured to manipulate two-dimensional (2D) images and to composite separately-generated stored three-dimensional (3D) image stored in a frame buffer, and a next 3D image, [images,] comprising,

a color data channel adapted to receive Z coordinate data and color data of a next 3D image;

an image compositing module configured to perform [depth testing and stencil testing on specific components of next image, wherein said specific components are separately and sequentially processed by the imaging pipeline such that stencil testing of any one pixel is performed after depth testing for all pixels,]

[wherein said] a depth test [is performed] to [first] determine which [of the stored and next] 3D image is to be rendered at each pixel based on Z coordinate data of the next image received over the color data channel, and Z coordinate data of the stored 3D image, and to store the Z coordinate data of the 3D image to be rendered at that pixel in a depth buffer, [two images,] and [wherein] a [said] stencil test [is performed using the results of said depth test] to form a stencil mask identifying which 3D image is the image that is to be rendered at each pixel,

wherein the imaging pipeline, in response to receipt of color data over the color data channel, updates a color buffer to have stored therein color data of the 3D image to be rendered at each pixel of the composite image. [first determination is performed on Z coordinate data of the stored and next images while said second determination is performed on color data of the next image.]

30. (Amended) The graphics system of claim 28, wherein the graphics system comprises a rendering pipeline comprising: [including,]

a geometric pipeline constructed and arranged to create a two-dimensional image from [one or more model views defined by] primitive data; and

said imaging pipeline.

31. (Amended) A graphics system comprising a graphics application controlling a 2D imaging pipeline to composite a first 3D image and a second 3D image generated separately than the first image, wherein the imaging pipeline processes Z coordinate data of the images to determine, for each pixel in the composited image, which of the first or second 3D image is closest to a viewpoint, and stores [causes] color data of the closest 3D image [to be stored] in a frame buffer for [subsequent] rendering on a display device.

MARKED UP VERSION OF SPECIFICATION
SHOWING ALL CHANGES MADE

[ATTACHMENT 3 TO THE AMENDMENT AND RESPONSE FILED IN RESPONSE TO THE OFFICE ACTION DATED APRIL 12, 2002 IN U.S. PATENT APPLICATION 09/547,065.]

The Title on page 1, lines 1-2

[COMPOSITING SEPARATELY GENERATED 3D IMAGES
USING A GRAPHICS RENDERING PIPELINE]

COMPOSITING SEPARATELY-GENERATED
THREE-DIMENSIONAL IMAGES